

# GODDARD APPLIED SCIENCES

## 2018 HIGHLIGHTS

Goddard Applied Sciences brings together NASA's Earth Observations and scientific expertise for societal benefit.

The Goddard Applied Sciences team coordinates projects funded by a variety of NASA programs and missions, connects NASA researchers with end users, supports interagency activities, and develops lasting external partnerships.



# GODDARD APPLIED SCIENCES TEAM



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# Air Quality & Public Health

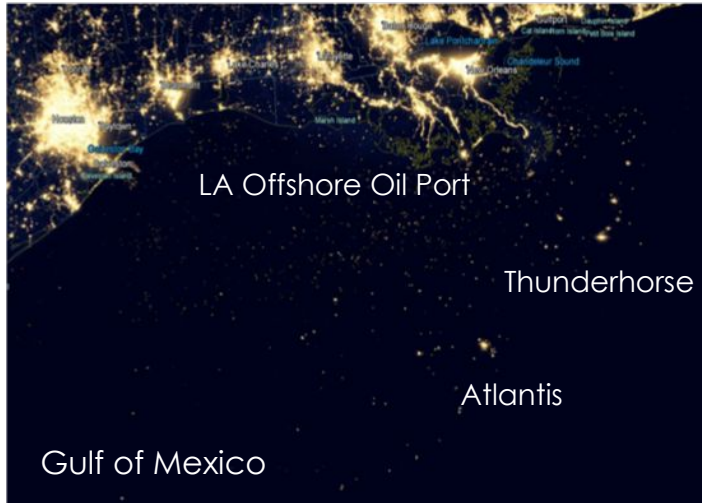


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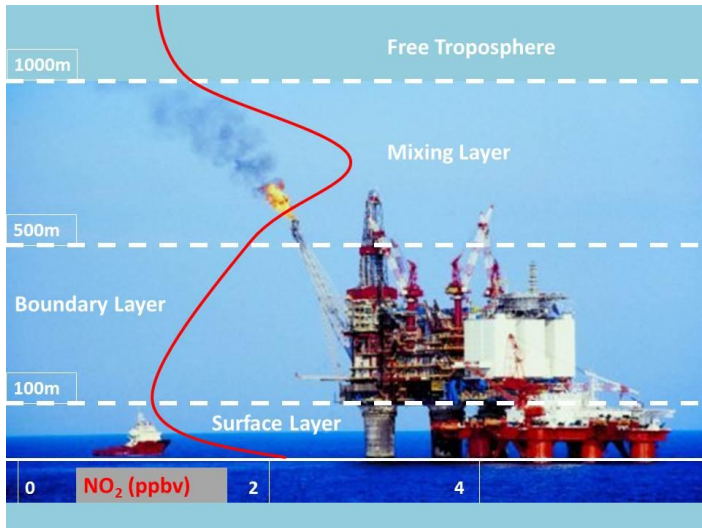
# Using NASA Earth Observations to Monitor Offshore Air Quality



NASA and the Bureau of Ocean Energy Management (BOEM) have entered into an inter-agency agreement to evaluate the potential for using satellite data to monitor offshore air quality.

BOEM aims to assess how pollution from shipping and oil, and natural gas activities in the Gulf of Mexico affects air quality on land. Toward this goal, NASA scientists will document the current state of satellite data products over the Gulf of Mexico, including oil slicks (MODIS), lights at night (VIIRS) (*upper left*), flare detection (VIIRS),  $\text{NO}_2$  (OMI),  $\text{SO}_2$  (OMI), aerosols (MODIS, MISR), and formaldehyde (OMI, OMPS).

A planned field campaign in the Gulf of Mexico will help scientists evaluate how well air pollution can be monitored from space. Research vessel measurements will identify needs for improvement in satellite retrieval algorithms over open water, including vertical air pollution plume variability (*example vertical profile shown as red line, lower left*).



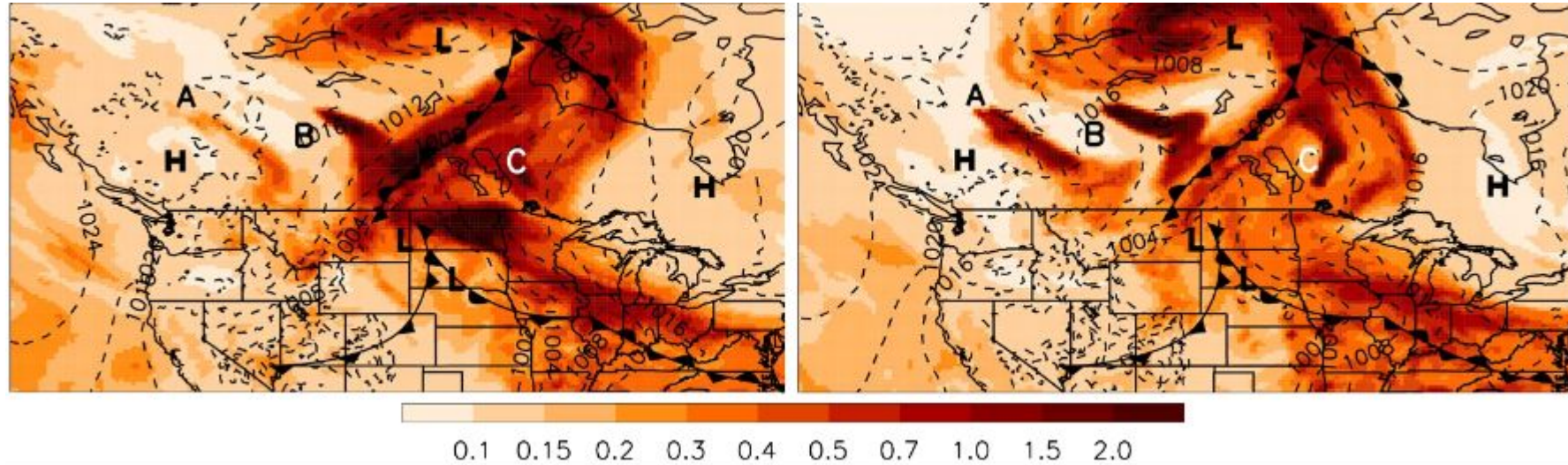
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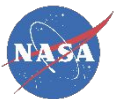


# Forecasting Ft. McMurray Fire with NASA's GEOS-5 Model

NASA data and weather models simulate the movement of smoke plumes from wildfires. NASA's new high-resolution modelling capabilities help emergency managers track the impacts of these fires, including on public health and air traffic.

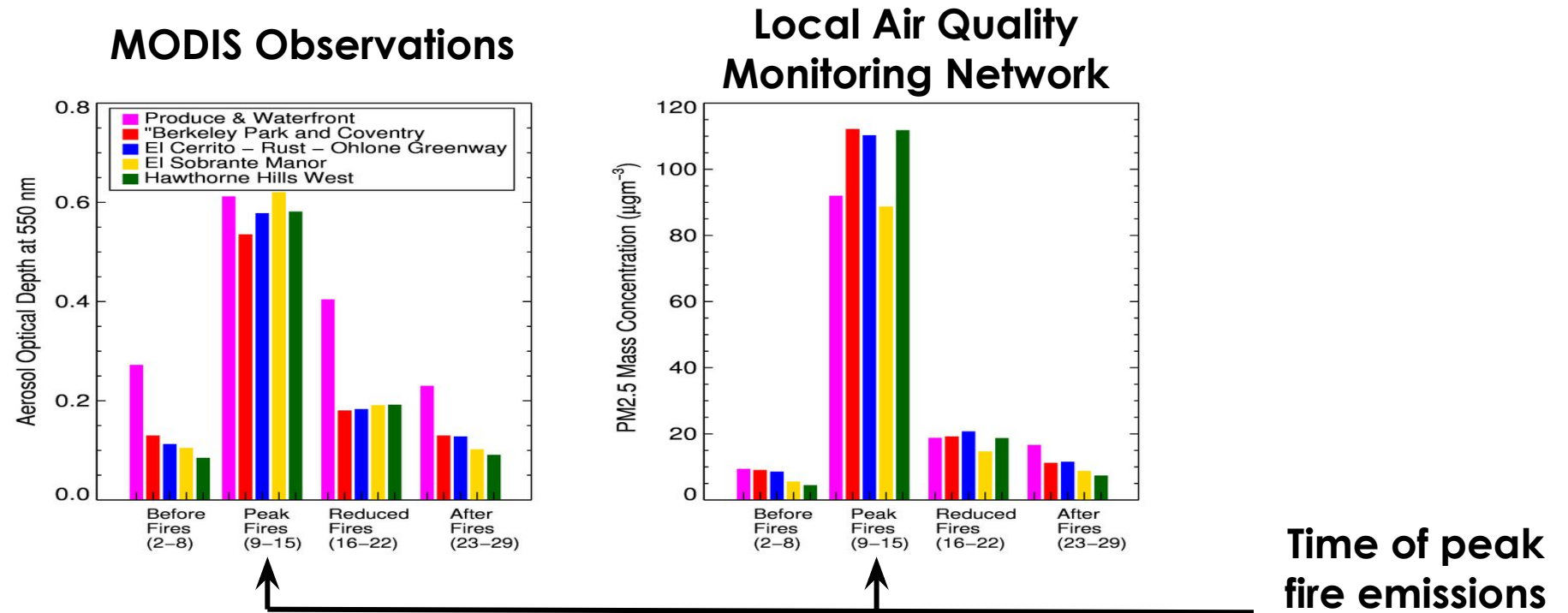


NASA's GEOS-5 model forecasts the evolution of fire pollution plumes in near real-time using a fire radiative power index based on weather observations and aerosols from the MODIS instrument. On May 10 2016, atmospheric observations reveal the influence of the Ft. McMurray fires across Canada (*left*). GEOS-5 forecasts (*right*) gave air quality managers an early warning, by correctly predicting the transport of pollution to North Dakota, Montana, and Minnesota three days in advance.



# California Fire Emissions Observed by Satellite and Local Network

NASA scientists are partnering with air quality management agencies and a network of low-cost air quality monitoring sensors to better understand how air quality varies across time and space in California.

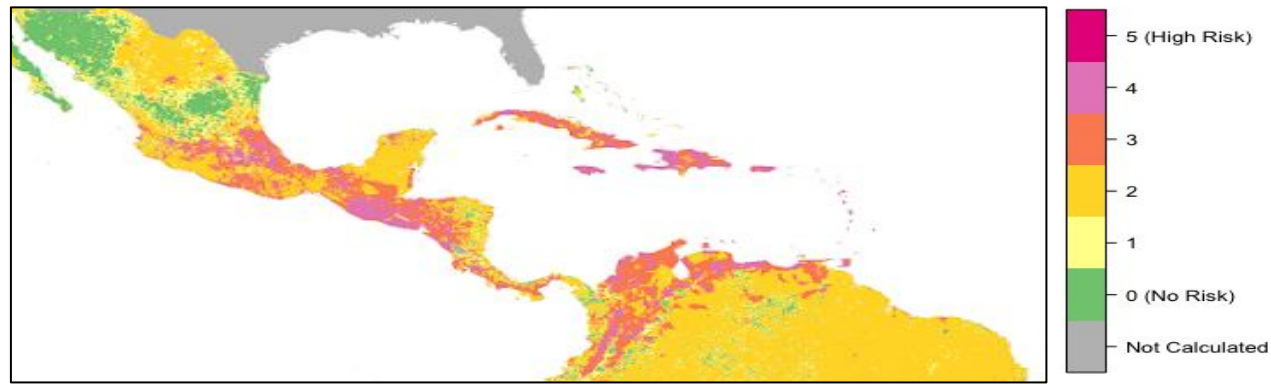


During California wildfires in October 2017, both satellite observations from the MODIS instrument (*above left*) and surface air quality measurements by local citizen scientists (*above right*) detected the fire emissions as sharp increases in atmospheric aerosol optical depth (AOD), or aerosol loading.



# Monitoring and Mapping Chikungunya Risk

CHIKRisk is a new app that utilizes NASA and NOAA satellite climate observations as model inputs to determine conditions leading to outbreaks of Chikungunya, a vector-borne disease. The US military and DoD strategic commands are using CHIKRisk disease risk maps (*below*) to guide health protection decisions prior to and during troop deployment. Also, Chikungunya risk maps are being by first responders at public health agencies such as the Centers for Disease Control (CDC).

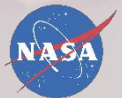


Cases of Chikungunya emerged in the Americas in 2013. Its rapid geographic spread demonstrates the importance of assessing the current range of the disease and mapping regions at risk. Higher than average land surface temperatures and densely populated areas tend to be at increased risk for Chikungunya.





# Capacity Building



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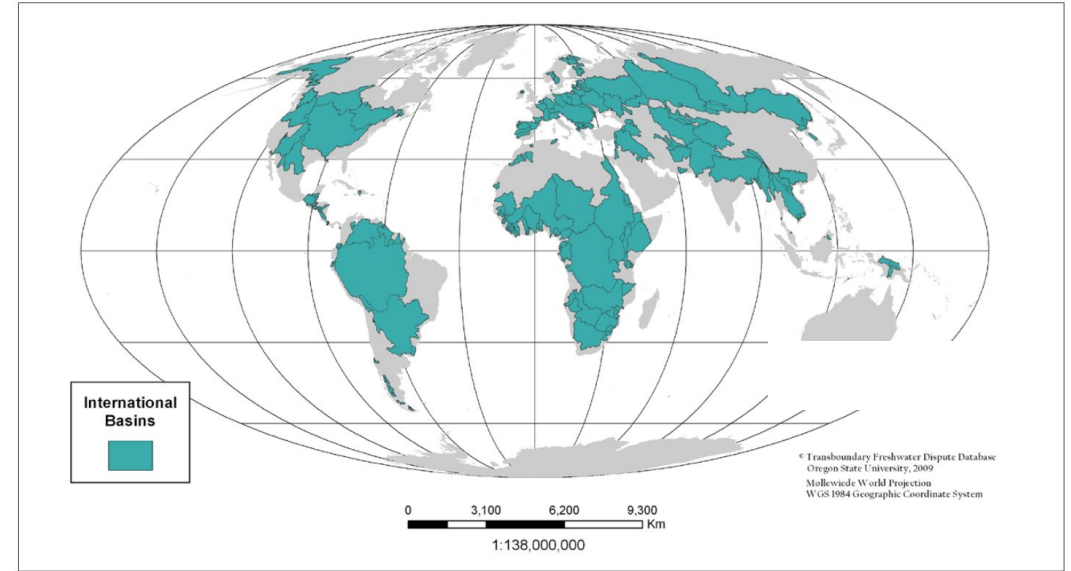
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# Supporting Transboundary Water Security

NASA, the US Army Corps of Engineers' Engineer Research and Development Center (ERDC) and the US Air Force (USAF) are working together to explore how US federal agencies could more effectively make decisions around transboundary water and water security issues. Forty percent of the world's population resides in one of 286 transboundary river basins (highlighted in green, right). In these basins, water-related stressors can lead to regional instability and conflict. Significant data and information gaps remain, in part due to data sharing challenges amongst nations in transboundary basins.



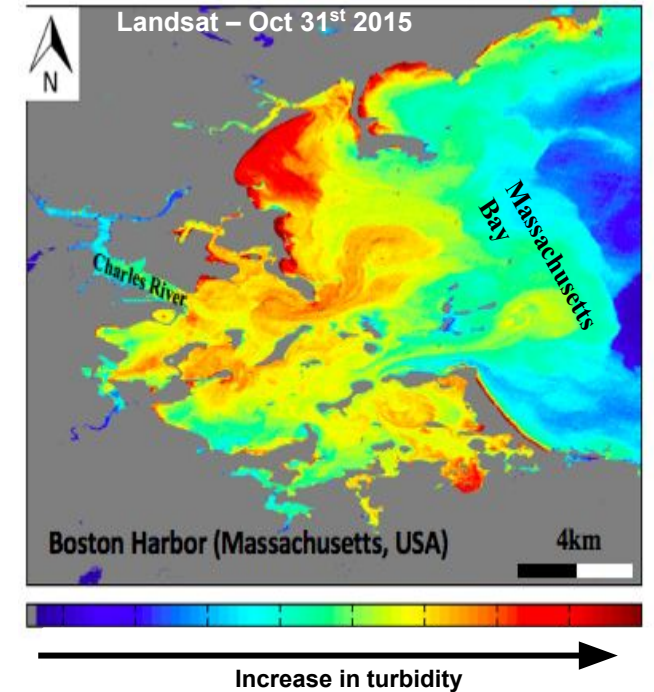
This effort has revealed that, though many science and technology tools exist, resources are often disconnected from decision-makers in the intelligence, defense and foreign policy communities. NASA, ERDC and USAF have formed a subcommittee of a State Department-led interagency working group to follow up on the priority actions identified during a joint workshop in 2017.



# Monitoring Water Quality in Near Real-Time

NASA Goddard is developing a near real-time water quality monitoring tool, based on Landsat-Sentinel imagery. The tool would complement existing field monitoring programs by automatically alerting water resource and ecosystem managers to potentially hazardous water quality conditions. Declining inland and coastal water quality has become a major environmental and economic issue, as human populations increase and extreme events such as algal blooms become more frequent.

In September 2017, NASA Goddard scientists introduced the near real-time alert system during a workshop with the water quality monitoring community. The workshop brought together more than 340 environmental specialists, economists, scientists, industry representatives, legal advisors from state and federal agencies, and the private sector. Workshop attendees recommended that the water quality warning system be automated, used to develop robust anomaly detection algorithms, and support ongoing implementation and calibration/validation efforts.



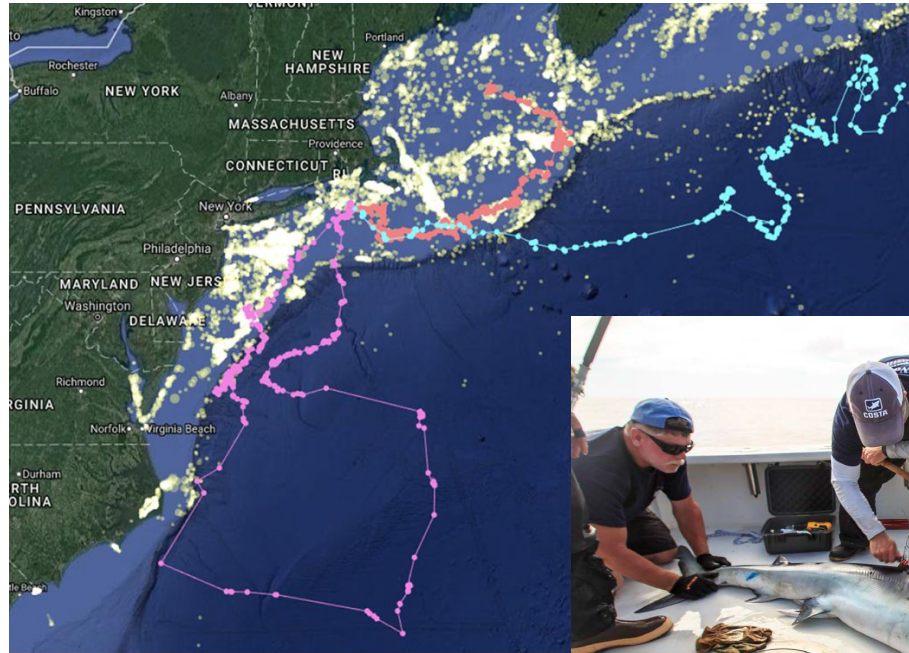
*This map of near-surface turbidity, derived from Landsat-Sentinel imagery, identifies potential biogeochemical hot spots. Field sampling is used to test potential hotspots for hazardous water quality.*



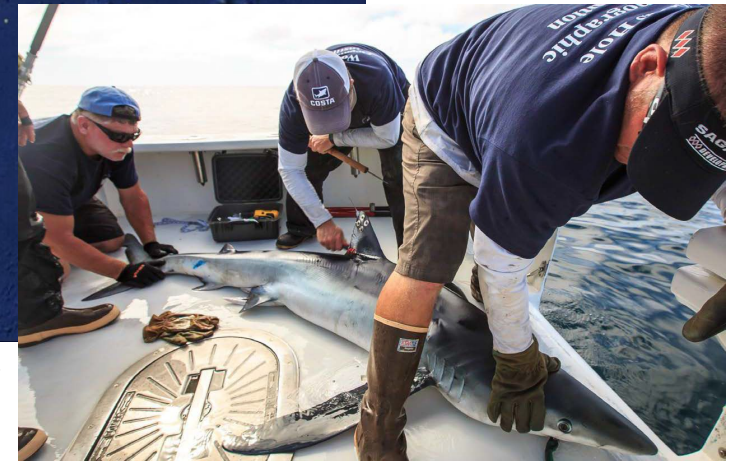
# Supporting Ocean Health and Fisheries with Earth Observations

A healthy ocean provides people with a source of food and livelihood, yet increased pollution, warming, changing chemistry, and overfishing threaten these resources. Space-based marine biological indicators, such as chlorophyll, and their response to multiple stressors guide sustainable management and conservation efforts.

NASA and the World Resources Institute co-hosted a workshop in Washington, DC in November 2017, in collaboration with NOAA. Monitoring the ocean from space comes with trade-offs between spatial, temporal, and spectral resolution. Users emphasized their need for locally actionable information that satellites alone cannot provide. For example, harmful algal bloom forecasts are not yet available at the small spatial scales desired by individual aquaculture farms.



Global Fishing Watch is a tool that shows the location of fishing vessel activity (yellow dots), here combined with shark tracks (colored lines). [Credit: Oceana]



Scientists tag sharks to track their movement in the North Atlantic. [Credit: MIT-WHOI]

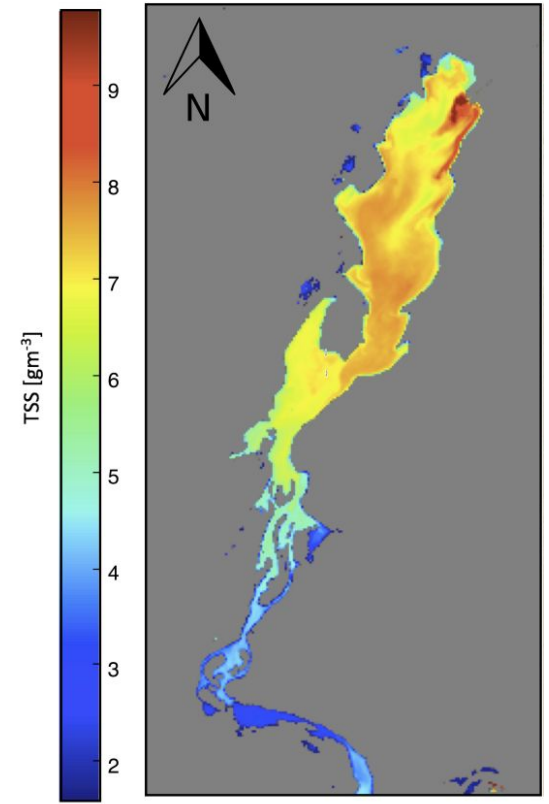




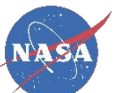
# Mapping Water Extent and Quality with Earth Observations

Using MODIS and Landsat datasets, NASA and the University of Maryland collaborated on a pilot study toward Sustainable Development Goal (SDG) #6 on water and sanitation. The pilot study team documented satellite-based methodologies for adoption by UN Environment and to assist countries with their SDG reporting.

The pilot study tested methodologies to both meet countries' reporting requirements for SDG Indicator 6.6.1 and track changes in the extent of water-related ecosystems over time. Specifically, the team mapped the spatial extent of inland waterbodies at two spatial resolutions for select countries, including Cambodia, Jamaica, Peru, Philippines, Senegal, Uganda and Zambia. Landsat and Sentinel were used to estimate Total Suspended Solids (TSS) and chlorophyll, two indicators of water quality, for select waterbodies. Landsat, Sentinel and Shuttle Radar Topography Mission (SRTM) data were used to estimate the spatial extent of coastal mangroves.



*Landsat-derived concentration of Total Suspended Solids (TSS) for Lake Guiers in Senegal. Warmer colors indicate more turbid waters. The highest TSS concentrations, to the north, are associated with areas where water flows into the lake from the Senegal River.*



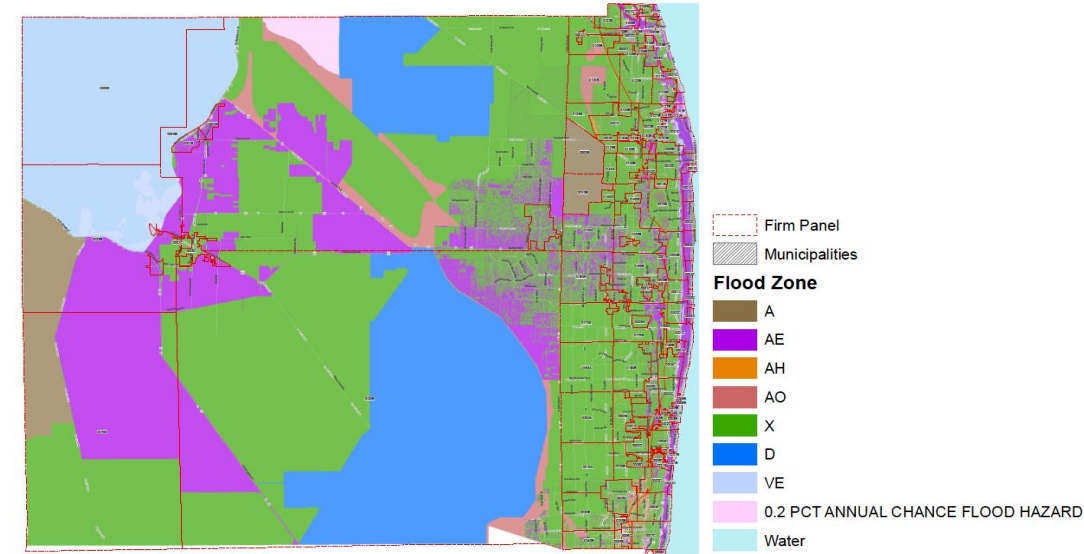


# FEMA Flood Map Developed Through ARSET Training

The Federal Emergency Management Agency (FEMA) worked with Dewberry, a company offering water resource planning and design services, to publish a preliminary flood insurance map for Palm Beach County (*right*). This was the first update to the county flood map since 1989. Dewberry used satellite data to compare areas flooded by Hurricane Irma in October 2017 with the new county flood map, allowing FEMA to address specific questions about flooding caused by Hurricane Irma.

During a NASA Applied Remote Sensing Training (ARSET) workshop, Dewberry analysts learned to apply Synthetic Aperture Radar data from Sentinel-1 and MODIS near real-time data for flood monitoring and management. Participants used satellite observations to evaluate extreme weather conditions, prepare for impending flooding, and plan relief activities.

**Palm Beach County Flood Map**



*"We are using the skills we learned at the workshop to determine the floodplain generated by [Hurricane] Irma ... Once we get sufficient expertise in accessing and processing satellite data, we plan to offer this skill to FEMA's emergency response group"*

*—Senior Engineer, Dewberry*



# Climate Applications



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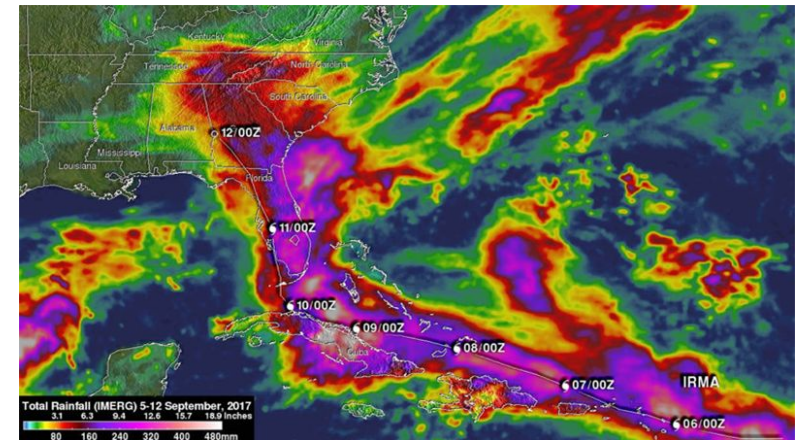
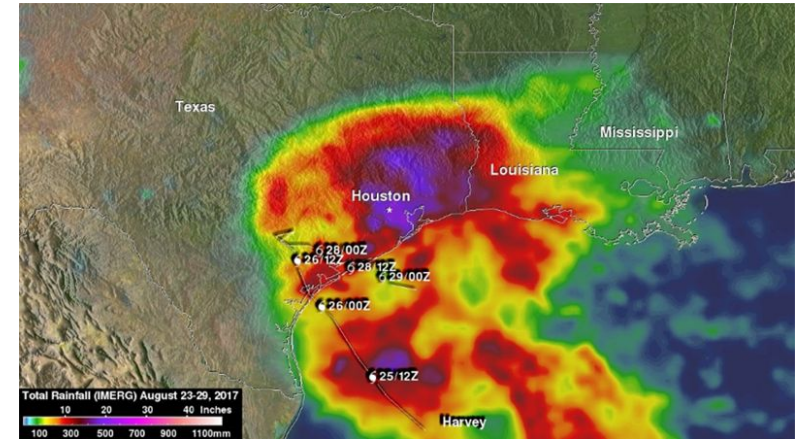
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# Preparing for Extreme Weather at NASA Facilities

NASA has taken action to prepare for the impacts of extreme weather and longer-term climate change on its facilities. This action has been taken in response to research by the Climate Adaptation Science Investigators (CASI) working group, composed of Earth scientists and NASA institutional stewards.

In September 2017, NASA's Johnson Space Center (JSC) in Houston and Kennedy Space Center (KSC) on Florida's Atlantic coast experienced heavy rainfall associated with Hurricanes Harvey and Irma (*right*). While the hurricanes impacted both facilities, preemptive actions lessened the damage that might have otherwise been sustained. KSC was closed prior to and during the storm. Elevated building systems and improved stormwater drainage prevented widespread flooding at JSC. More generally, these actions could be taken by hurricane-prone regions of the US to reduce the risks of coastal and inland flooding.



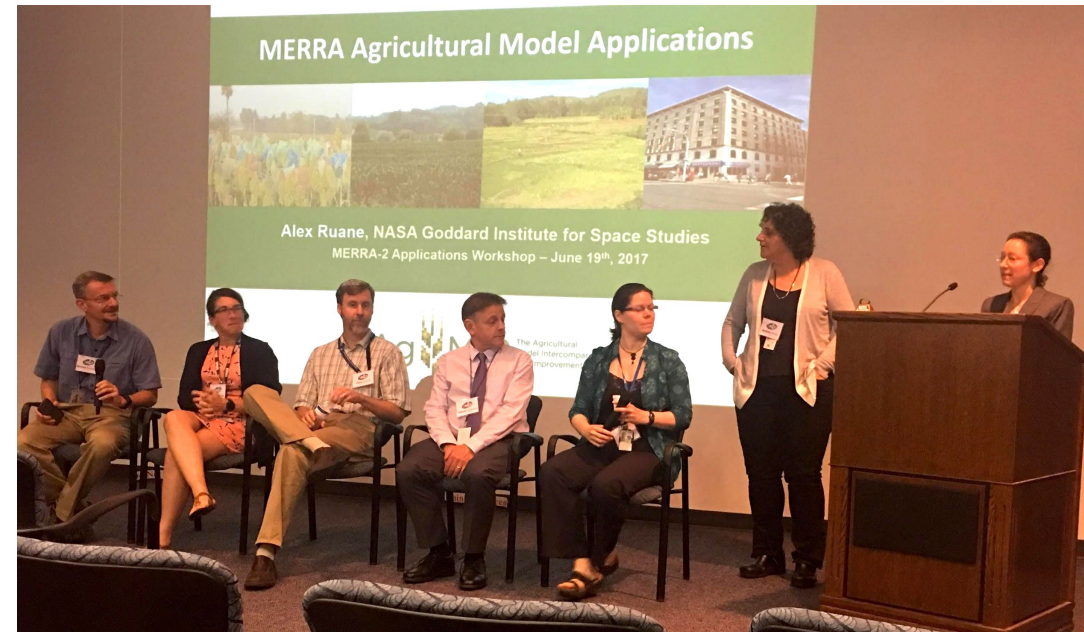
NASA IMERG product shows heavy rainfall associated with Hurricanes Harvey (upper panel) and Irma (lower panel). These storms impacted JSC and KSC, respectively.



# Applications of the MERRA-2 Reanalysis in Earth Science and Beyond

NASA's Modern-Era Retrospective analysis for Research and Applications, Version 2, or MERRA-2 reanalysis, combines NASA observations with the GEOS-5 numerical ocean-atmosphere model. MERRA-2 is being widely used to analyze extreme weather events, in longer-term planning and design for climate variations, and to provide the initial climate conditions to drive decision-support tools, such as those used to forecast food security.

In June 2017, the MERRA-2 Applications Workshop brought together 80 professionals representing US government agencies, academia, non-governmental organizations and the commercial sector. The workshop provided an overview of NASA's computing resources that allow users to manage this very large data collection. The workshop highlighted applications of the MERRA-2 reanalysis in and beyond Earth science, such as to support renewable energy operations and public health research. NASA Goddard scientists facilitated discussions of end users' technical challenges, such as calculating trends and reducing the data latency.



*NASA panelists discussed the merits of MERRA-2 for end users, as well as the potential evolution of the MERRA series of products.*

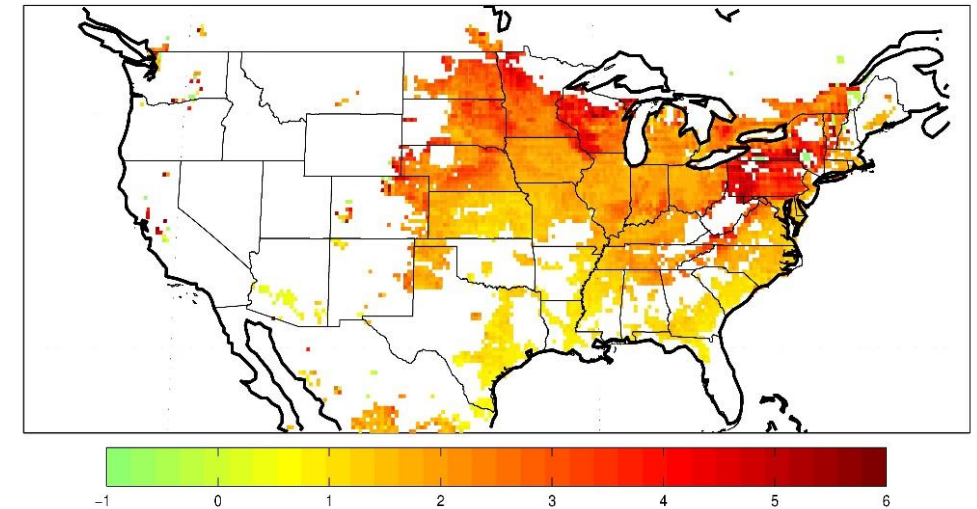




# Assessing Vulnerability of US Agriculture to Climate Change

NASA partnered with the US Department of Agriculture to investigate how climate change could affect future US and global agricultural production, as well as the resulting impacts on agricultural markets. Climate-induced production shifts drive changes in land area devoted to major cereal crops and affect global food prices.

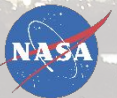
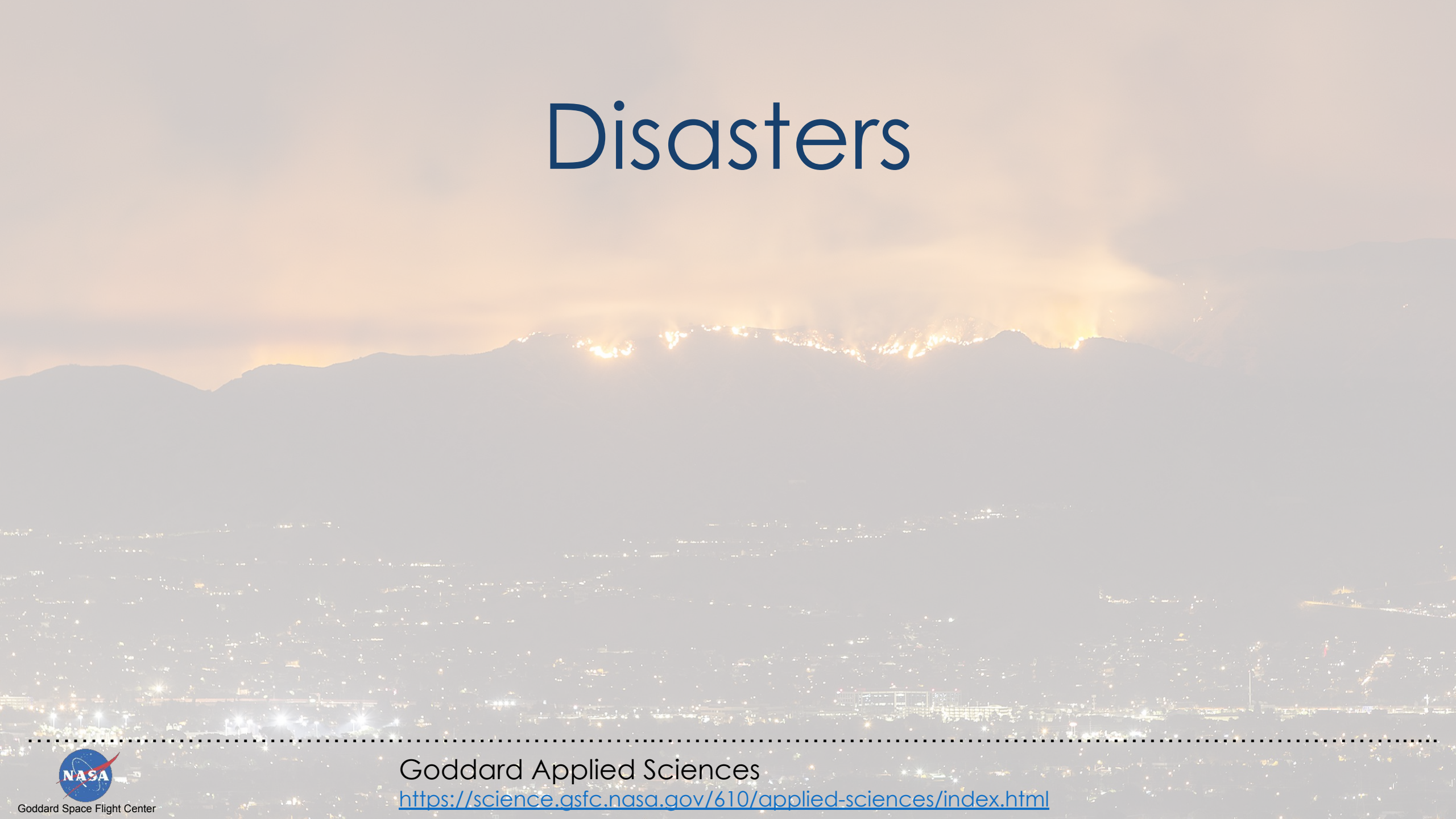
US agricultural systems face growing pressures from warming temperatures, changing precipitation patterns and rising carbon dioxide concentrations. NASA scientists employ crop models to assess the response of US systems to climate changes, identifying key thresholds of impacts in order to prioritize adaptation strategies (*right*). Crops respond differently to climate shocks at the local and global level, leading to market changes affecting land use and food prices.



Colored shading shows the threshold (°C) needed to reduce rainfed corn yield by 15%. This threshold is lowest in southern agricultural regions (yellow shading), suggesting that these regions are most vulnerable to a warming climate.



# Disasters



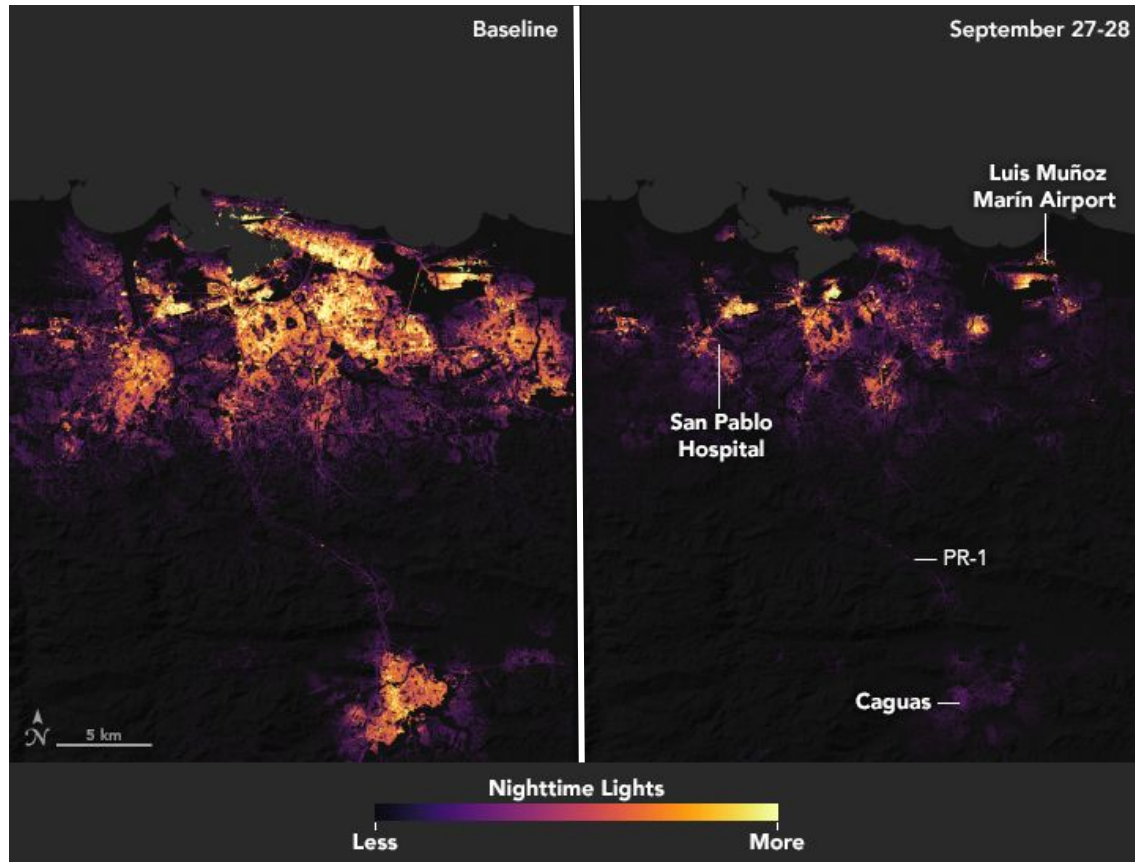
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# Pinpointing Post-Hurricane Power Outages in Puerto Rico



In September 2017, Hurricane Maria caused significant damage to infrastructure in Puerto Rico, resulting in widespread power outages (left).

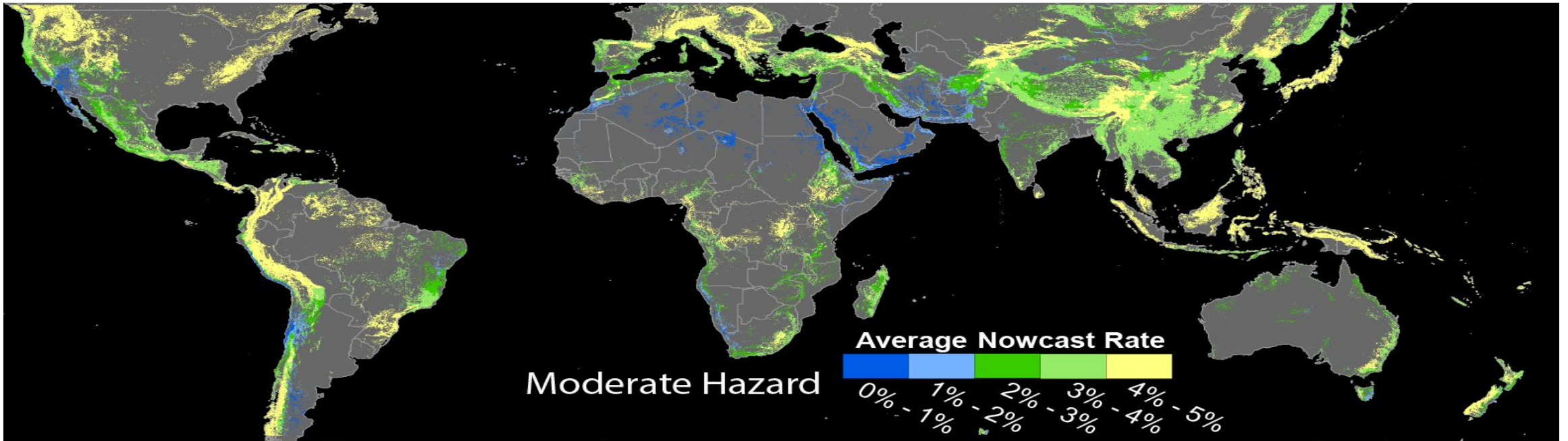
NASA's Black Marble products, based on data from the VIIRS instrument, provided detailed maps of changes in nighttime lights. These maps enabled federal and local government authorities, construction and utility crews, and relief organizations to understand the extent of power outages and infrastructure damage, and prioritize mitigation actions.

NASA's Black Marble High Definition (HD) products enable the first-ever monitoring of disaster-affected areas at neighborhood scales (~30m), by scaling quality-controlled VIIRS observations onto a base map that includes the precise locations of streets and buildings.



# New Model Shows Global Landslide Seasonality

A landslide model that brings together susceptibility information with satellite rainfall from the Global Precipitation Measurement (GPM) mission provides near real-time estimates of potential landslide activity around the world to support disaster response. The model has also been used to understand the seasonality of landslide activity retrospectively, considering data from 2001 to 2016.



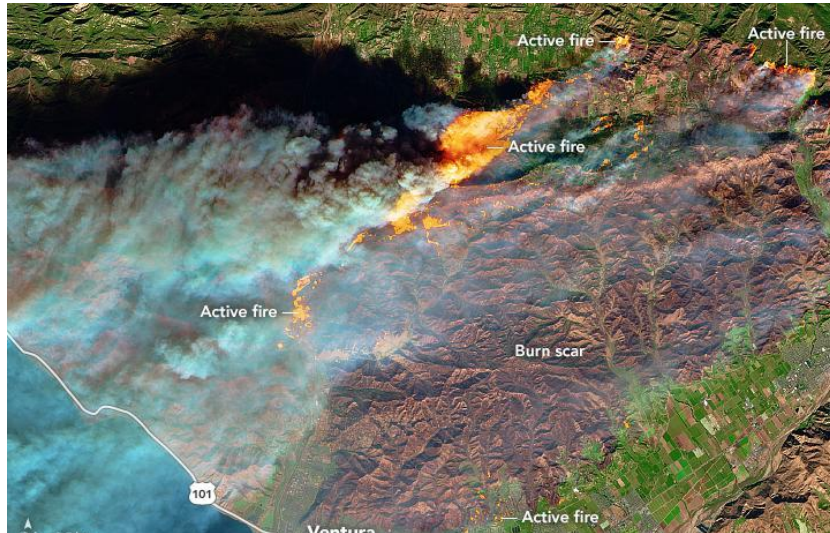
The open source model is currently being used by a range of end users, including at the city scale in areas such as Rio de Janeiro, Brazil to better understand potential landslide hazard areas, and to inform hazard situational awareness by the U.S. Army Geospatial Center.



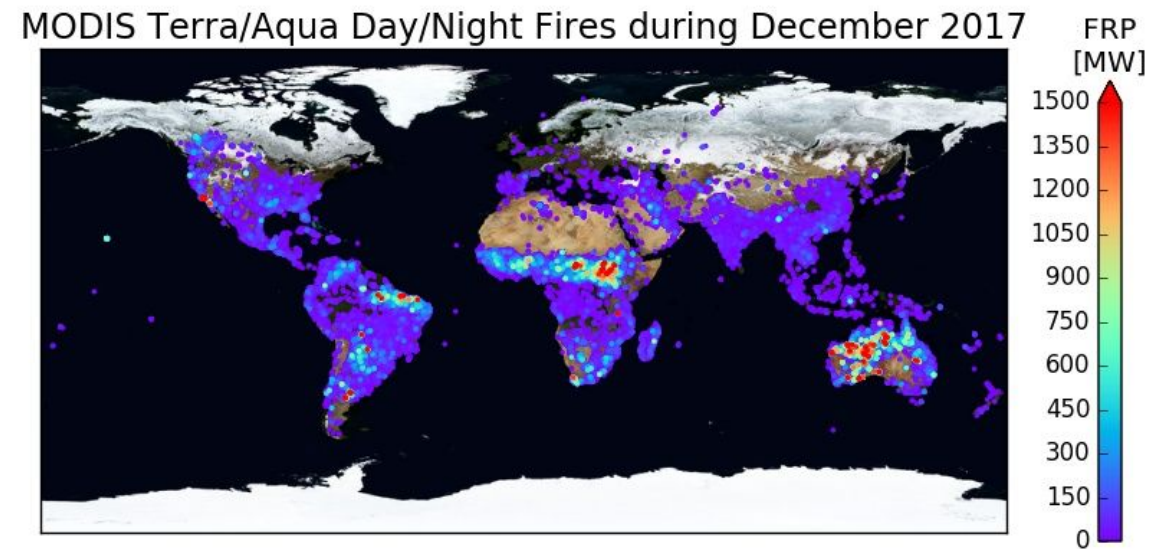


# NASA Satellites Track Fires and Burned Areas

NASA satellites often provide the first indication of fire occurrence, and represent a consistent source of accurate information for local officials about the relative location, size and severity of fires. NASA has built a decades-long record of global fires.



The European Space Agency's Sentinel-2 satellite was used to identify active fires and burn scars in Southern California in December 2017 (above). NASA and partner satellites can track active fires in the context of recently burned areas. These maps inform local emergency managers as they plan intervention and recovery efforts and determine how to best use their limited resources.

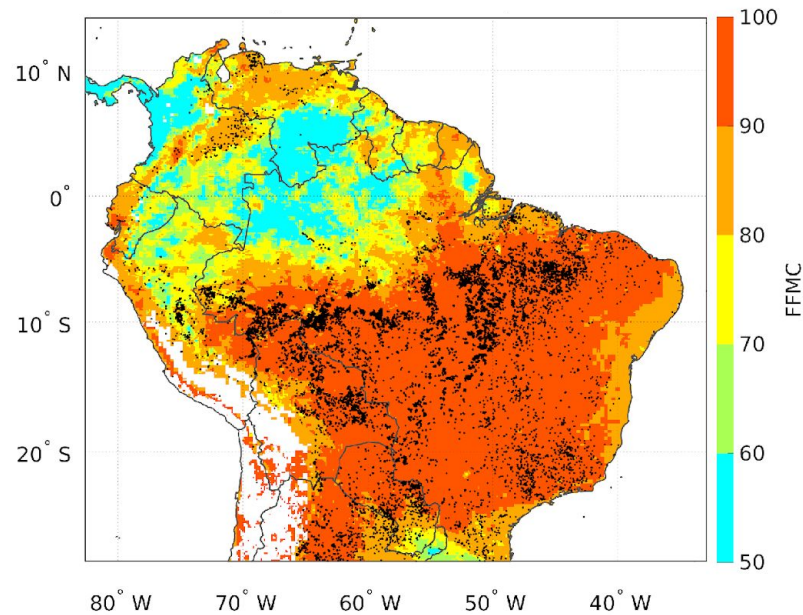


MODIS and VIIRS data are used to construct maps of active fires and their fire radiative power (FRP) or strength (above). The US Forest Service uses these maps to make decisions in near real-time.

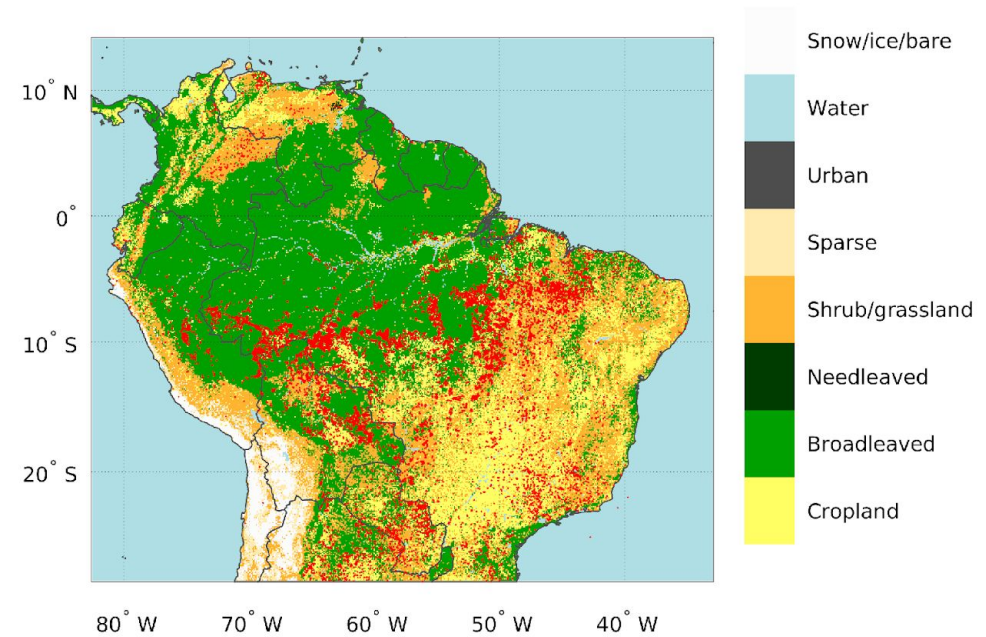


# Understanding How Weather Drives Fire Activity

NASA's Global Fire Weather Database combines several weather variables to understand the meteorological drivers of fire around the world. IMERG, a NASA rainfall product, is combined with temperature, relative humidity and wind speed to calculate indices of the potential for fires to start, spread and do damage.



*The Fine Fuel Moisture Code (above, colored shading) uses IMERG precipitation to track the moisture content of fine fuels where fires can easily start, for example in the Amazonian 'Arc of Deforestation'.*



*Fire activity patterns (above, red dots) can be understood by overlaying fire potential indices with land cover classifications (colored shading).*



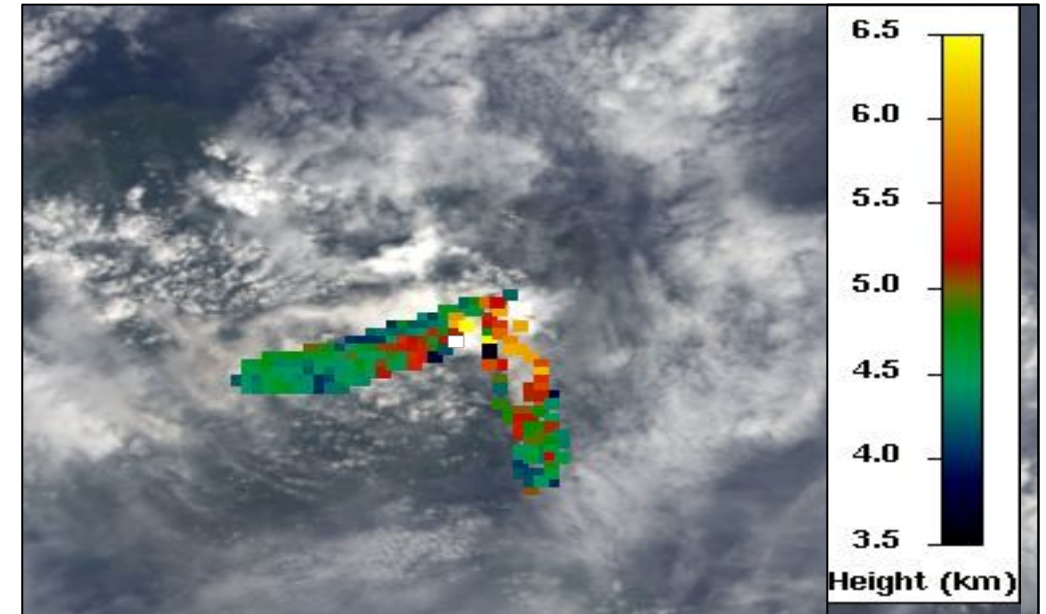


# Measuring Volcanic Plume Height

On November 29 2017, NASA's Multi-Angle Imaging Spectroradiometer (MISR) instrument observed a volcanic plume from Agung volcano in Bali, Indonesia. Images taken at different angles make it possible for MISR to retrieve volcanic plume heights and help distinguish volcanic eruption plumes from weather-related clouds.

Volcanic eruptions can generate significant amounts of airborne ash particles that, depending on the volcanic plume height, can cause regional or larger-scale hazards.

MISR data on this day showed two volcanic aerosol plumes (right), one trending south and reaching an altitude of ~6 km, and the other trending southwest over Bali at ~4.5-5 km elevation. As these plumes become sub-visible within ~ 30 km of the source, relatively little ash was emitted, suggesting that their effects likely remained local. Volcanic ash plumes can pose a hazard aircraft, by scouring windshields and destroying engines. A larger eruption from Agung volcano could impair the busy Australia–Southeast Asia flight corridor.





# Urban Environments



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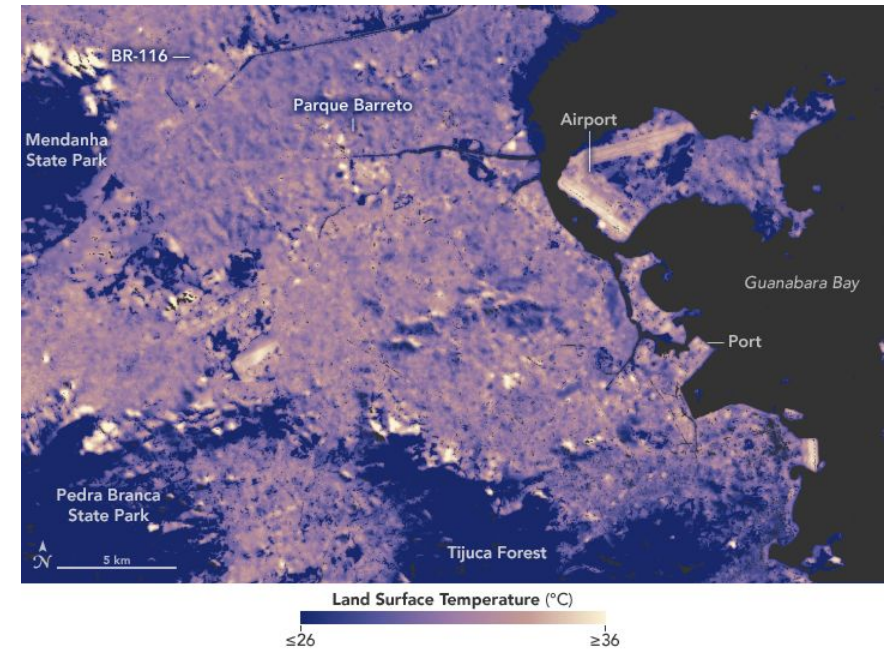


# NASA and Rio de Janeiro Expand Collaboration

NASA and the City of Rio de Janeiro are partnering to better anticipate natural hazards and become more resilient to environmental pollution and climate impacts. Bringing NASA's Earth-observing satellites and climate projections together with key data collected by the City of Rio de Janeiro provides an integrated view of the city, facilitating geophysical monitoring and decision-making. NASA and Rio have active scientific collaborations in air quality, water quality, landslide risk, sea level rise and urban heat islands *(right)*.

Two series of educational webinars introduced Rio de Janeiro's teachers and students to Earth science, and to NASA and Rio de Janeiro's environmental monitoring activities.

NASA is helping to translate Rio de Janeiro's achievements to other cities through its engagement in city networks, such as the C40 Cities Climate Leadership Group, and through participation in scientific conferences.



*Landsat-based land surface temperature in Rio de Janeiro in August 2016. Lighter colors indicate Rio's 'urban heat island' and correspond with higher temperatures and built-up areas (photo credit: NASA Earth Observatory).*



# Microsoft and NASA Partner to Enhance Urban Resilience

NASA and Microsoft are partnering to create an Urban Environmental Data Dashboard. A Chicago pilot project is focused on enhancing urban planning and emergency response to extreme heat, with local stakeholders including the Chicago Department of Public Health, the Office of Emergency Communications and ComEd, the local electric utility. The Urban Environmental Data Dashboard tool will provide city decision-makers with historic and real-time weather and climate information from ground observations, local sensor deployments, MODIS and Landsat datasets, and model-based products such as NASA's MERRA-2 reanalysis.



*Landsat image of the Chicago area.*

The NASA-Microsoft partnership represents an opportunity for NASA to bring Earth observations to urban stakeholders. While NASA brings expertise in remote sensing and Earth science analysis, Microsoft brings extensive experience in software development and data accessibility, as well as a desire to understand stakeholders' needs.



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# Water Resources & Food Security



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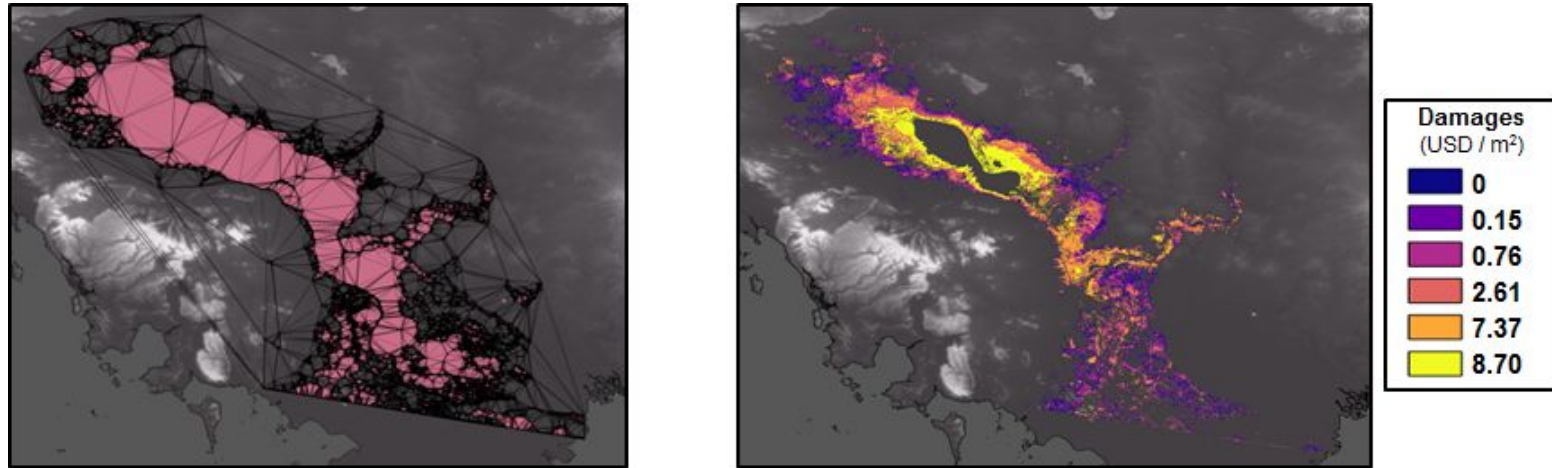
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# Flood Detection and Impact Assessment in the Mekong River Basin

NASA's MODIS observations, socioeconomic, and historical flood data are being used by regional stakeholders, including the Mekong River Commission and Asian Disaster Preparedness Center, to rapidly identify floods and associated impacts to people and infrastructure in the Lower Mekong region in near real-time.



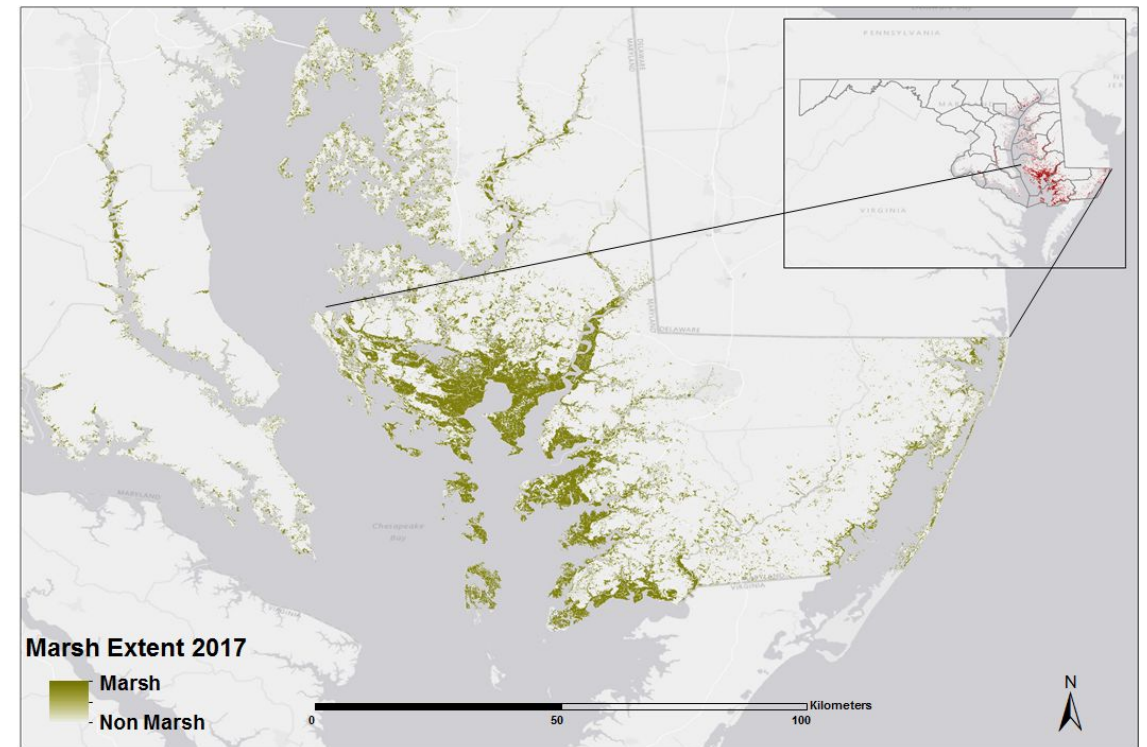
MODIS-derived surface water extent is used to produce flood depth estimates in near real-time (*above left*). Flood depth estimates are then fed into a standardized flood damage framework to produce damage estimates (*above right*) based on inundated land cover and affected infrastructure. These rapid, initial estimates of the socioeconomic impacts of extreme flooding provide valuable information to governments, international agencies, and disaster responders.



# Mapping Marsh Extent in the Chesapeake Bay

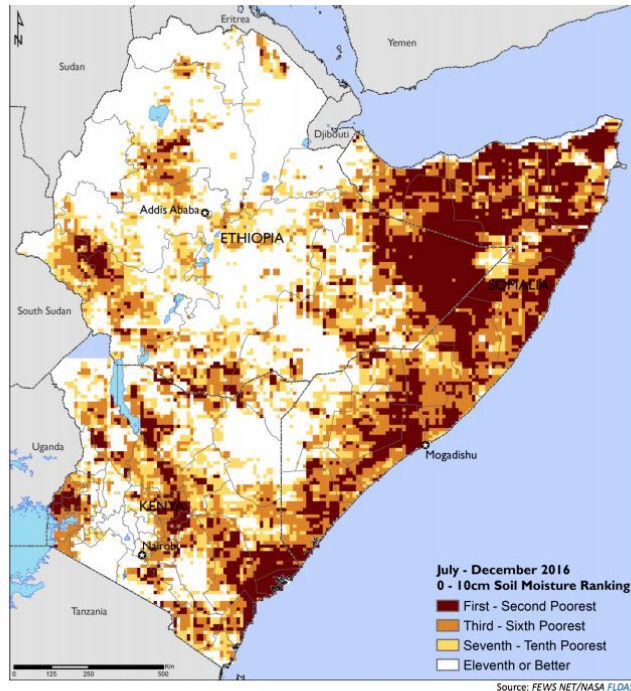
In 2016, Maryland's Coastal Resiliency Assessment identified regions where natural habitats provide the greatest potential protective benefits for coastal communities. Healthy marshes were determined to have high risk-reduction potential. A NASA DEVELOP team partnered with the Maryland Department of Natural Resources (DNR) and The Nature Conservancy (TNC) to measure marsh extent throughout Maryland's Chesapeake Bay.

The NASA DEVELOP team used Landsat imagery to create an interactive tool to map the presence and absence of marshland in the Chesapeake Bay in 2017 (*green shading, right*), as well as changes in marsh extent from the mid-1980s through the present. The Maryland DNR plans to use this tool to monitor marshland, which will inform restoration and conservation decisions for the Chesapeake Bay.



# Soil Moisture Model Provides Famine Early Warning

The Famine Early Warning Systems Network (FEWS NET) uses NASA's Land Information System (LIS) to monitor agricultural and water resources in Africa. In February 2017, drought conditions in Somalia (lower left) negatively impacted livestock, crops and food security (lower right).



"Somalia is facing a "very real risk" of famine, with more than 6 million people, half its population, facing acute food insecurity in the country, three UN agencies have warned."

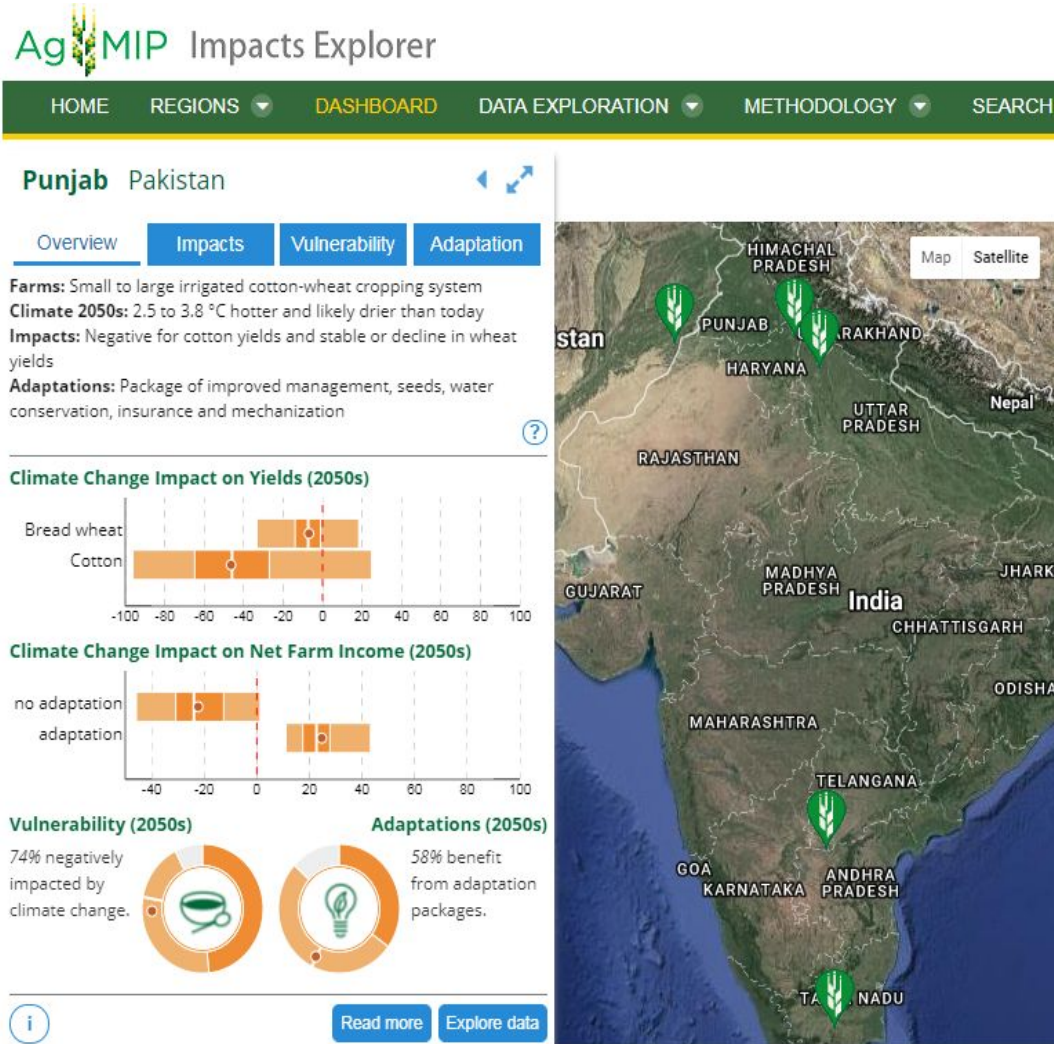
-The Guardian, 3 February 2017

Early warning systems help optimize the distribution of limited humanitarian aid resources. NASA satellite datasets are used to corroborate modeled estimates of quantities such as soil moisture. FEWS NET, the US Agency for International Development (USAID) and the US Geological Survey (USGS) use these datasets to create visualizations that meet the needs of the humanitarian community.





# Physical and Social Pressures Shape Future Farming Systems



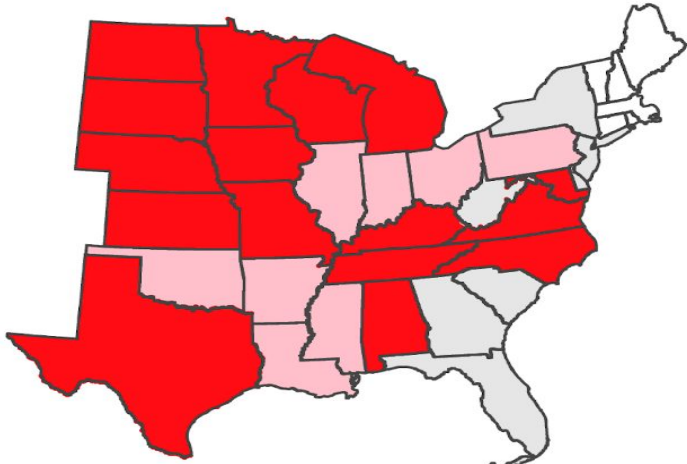
The Agricultural Model Intercomparison and Improvement Project (AgMIP) is a NASA-led effort organizing the international climate, crop, livestock, economics, and nutrition communities to assess current and future challenges for the agricultural sector and food security.

AgMIP and the UK Department for International Development engaged scientists and stakeholders across Africa and South Asia, disentangling the effects of socioeconomic development, climate change, and technological adaptation in shaping future farming systems. The AgMIP Impacts Explorer (example graphics shown at left) succinctly conveys the key messages of this work via maps and infographics. Stakeholders are incorporating agricultural projections into regional planning and investment decision-making.

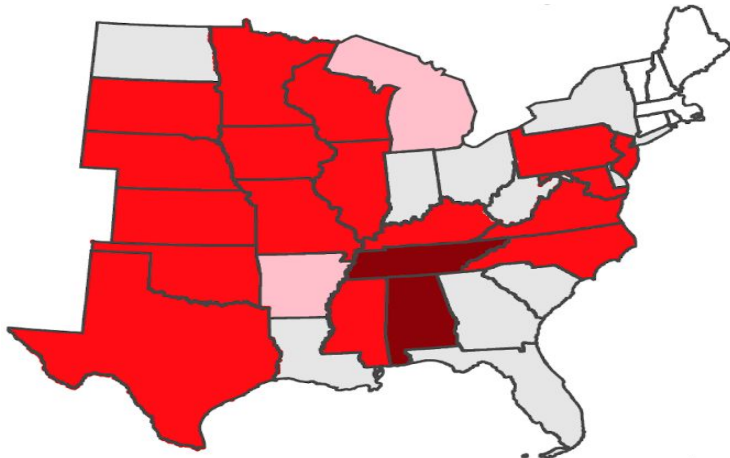


# Soil Moisture Merged Product Improves Agricultural Forecasting

Satellite merged product



Field survey



NASA's soil moisture products have been incorporated into the USDA Foreign Agricultural Service's operational agricultural forecasts to monitor global drought and predict long- and short-term impacts on vegetation health and agricultural yields. Merging satellite- and model-based products improves estimates of end-of-season crop yields. The merged satellite and model estimates provide comparable or better performance as compared with costly and labor-intensive survey-based methods.

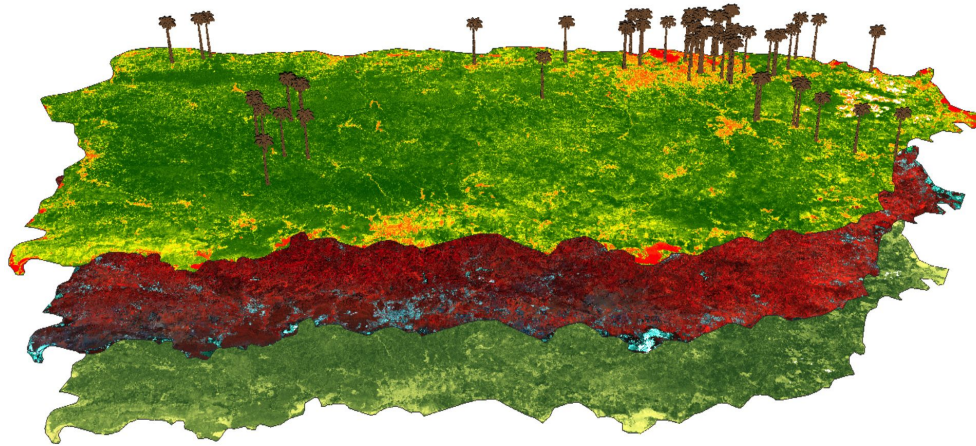
The satellite merged product (*upper left*) provided equal or better predictions of end-of-season corn yields for the central and eastern US for the August 2003-2010 period, compared to estimates from field surveys (*lower left*).





# Mapping the Spread of Red Palm Mite in Puerto Rico

The USDA Agricultural Research Service (ARS) is leading a multinational effort to stop the spread of red palm mite. Understanding the impacts of the red palm mite in Puerto Rico will help the USDA's broader-scale efforts to track this invasive species from space. The distribution of the red palm mite in Puerto Rico was mapped using NASA Landsat images and aerial imagery of the damaged crops (*below*). Results were distributed to researchers at the University of Puerto Rico.



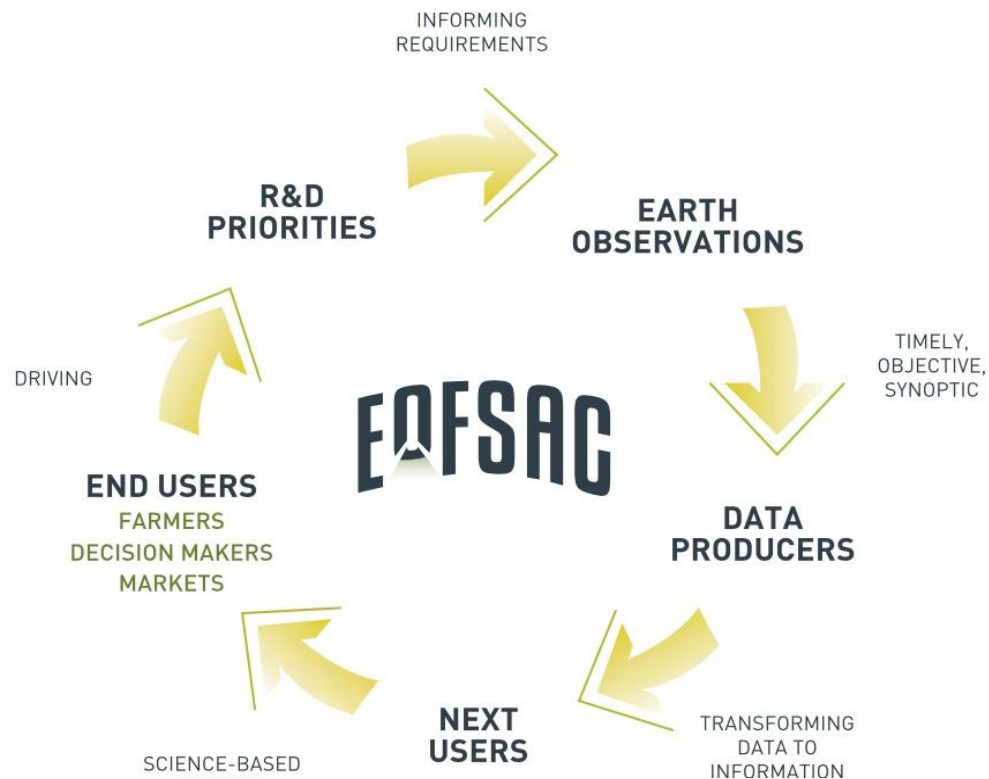
The red palm mite, a microscopic invasive species that devastates coconut palm, banana, and plantain crops, is spreading rapidly throughout the Americas and the Caribbean. Red palm mites feed on plant hosts' leaves, resulting in a characteristic pattern of leaf yellowing (*above*).





# NASA Launches Program for Food Security & Agriculture

Global food security represents a major societal challenge for the coming decades. In 2017, NASA established an agency-wide Food Security Office, located at NASA Goddard, and awarded the Earth Observations for Food Security and Agriculture Consortium (EOFSAC), based at the University of Maryland.



Combining the expertise of more than 40 researchers, humanitarian aid organizations, economists, policymakers, agribusiness, as well as the financial, intelligence and defense sectors, the EOFSAC aims to increase food security and resiliency, reduce price volatility, and improve awareness and understanding of the applications of NASA's satellite data products by end users.

*"Satellite data can help identify... variability in soil, crop conditions, and yield status. The goal of this new consortium is to get this data into the hands of more people making decisions about agriculture and food production."*

– I. Becker-Reshef (Principal Investigator, EOFSAC)

